Large Scale Tests of Vaporous Hydrogen Peroxide (**VHP®**) for Chemical and Biological Weapons Decontamination

George Wagner, Larry Procell, David Sorrick, Brian MacIver, Abe Turetsky, Jerry Pfarr, Diane Dutt, Mark Brickhouse

Edgewood Chemical Biological Center

Aberdeen Proving Ground, MD 21010

Lew Schwartz, Iain McVey, Paul Wiget, Steris Corp.

David Stark, EAI Corp.

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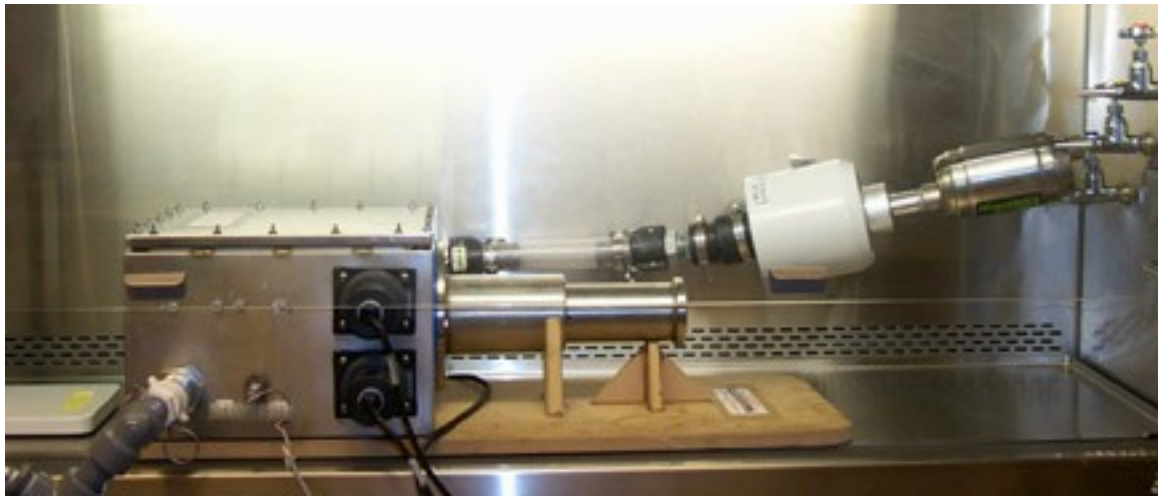
Steris **VHP®** Test Abstract

Vaporous Hydrogen Peroxide (VHP) has been used for more than a decade to sterilize clean rooms and pharmaceutical processing equipment and, more recently, to decontaminate anthrax-contaminated buildings. Recent studies at ECBC have shown that the addition of low-levels of ammonia gas renders VHP reactive towards GD, converting it to pinacolyl methylphosphonic acid. Thus, with suitable activation via ammonia gas, modified vaporous hydrogen peroxide (mVHP) affords the broad-spectrum decontamination of the chemical weapon (CW) agents VX, GD, and HD.* Studies at ECBC have also shown that mVHP is effective in decontamination of biological weapon (BW) surrogates, though mVHP does not at present appear to be substantially superior to standard VHP for biological decontamination. Potential applications of mVHP for military and civilian decontamination include: buildings, vehicle and aircraft interiors, and sensitive equipment.

Recent large scale tests of mVHP applicability for BW and CW decontamination were carried out in one of the ECBC Engineering Chambers, Building E3726. The study evaluated the use of mVHP to decontaminate BW agent surrogates and live CW agents on representative aircraft interior materials. These studies showed that at treatment levels of 250 ppm VHP and treatment times of 24 hours, residual contact hazard from chemical agents was reduced to the ORD required levels on all test materials, with the exception of decontamination of VX run at relatively low ammonia concentrations. These studies also showed that at treatment levels of 250 ppm VHP and treatment times of 24 hours, off-gas hazard from chemical agents was reduced to the ORD required levels for all test materials, with the exception of VX run at relatively low ammonia concentrations. The effect of ammonia concentration on BW and CW decontamination efficacy is currently under study.

***U.S. and international patents pending.**

Images of m**VHP**® Generator and D-Box Used for Biological Decontamination Studies



ECBC Large Chamber Tests

Steris M1000 **VHP®** Generators

1000 ft^3 Exposure Chamber

Large Chamber Test Design

- **Agents: VX, GD, HD**
- **Surrogates: DEPPT, TEP, CEPS, MPS**
- **2-4 μL agent deposited on test substrate coupon, allowed to age for one hour**
- **ca. 1000 ft^3 size chamber constructed inside larger chamber (E3726)**
- **Flow rate ~60 CFM**
- **Ambient Temperatures**
- **VHP® generated using 35 % H_2O_2 and two commercial M-1000 (Steris) VHP® Biodecontamination systems**
- **H_2O_2 injection rate ~75 g/min, to maintain ~ 275 ppm [H_2O_2] (measured)**
- **NH_3 gas introduced into VHP® stream just prior to its entering the chamber, to maintain ~ 20 ppm [NH_3] (calculated)**
- **Expose sample for 3, 8, or 24 hours**
- **Extract substrates using ethyl acetate**
- **Analyze extract by GC-MS (residual agent/products) (Detection limit ~1 ng)**

Large Chamber Test Substrates

- **Stainless Steel (blank)**
- **Glass (control)**
- **Chemical Agent Resistant Coating (CARC) painted steel (MIL-P-53039A)**
- **Aluminum 2024 (Spec T3) (uncoated)**
- **Air Force Topcoat-coated aluminum (MIL-P-85285-PU)**
- **Butyl rubber-covered cloth (Boeing insulation cover)**
- **Kapton (Polyimide) (wiring insulation)**
- **Nylon Webbing (MIL-W-4088, T3, C3)**
- **Concrete (Structural)**

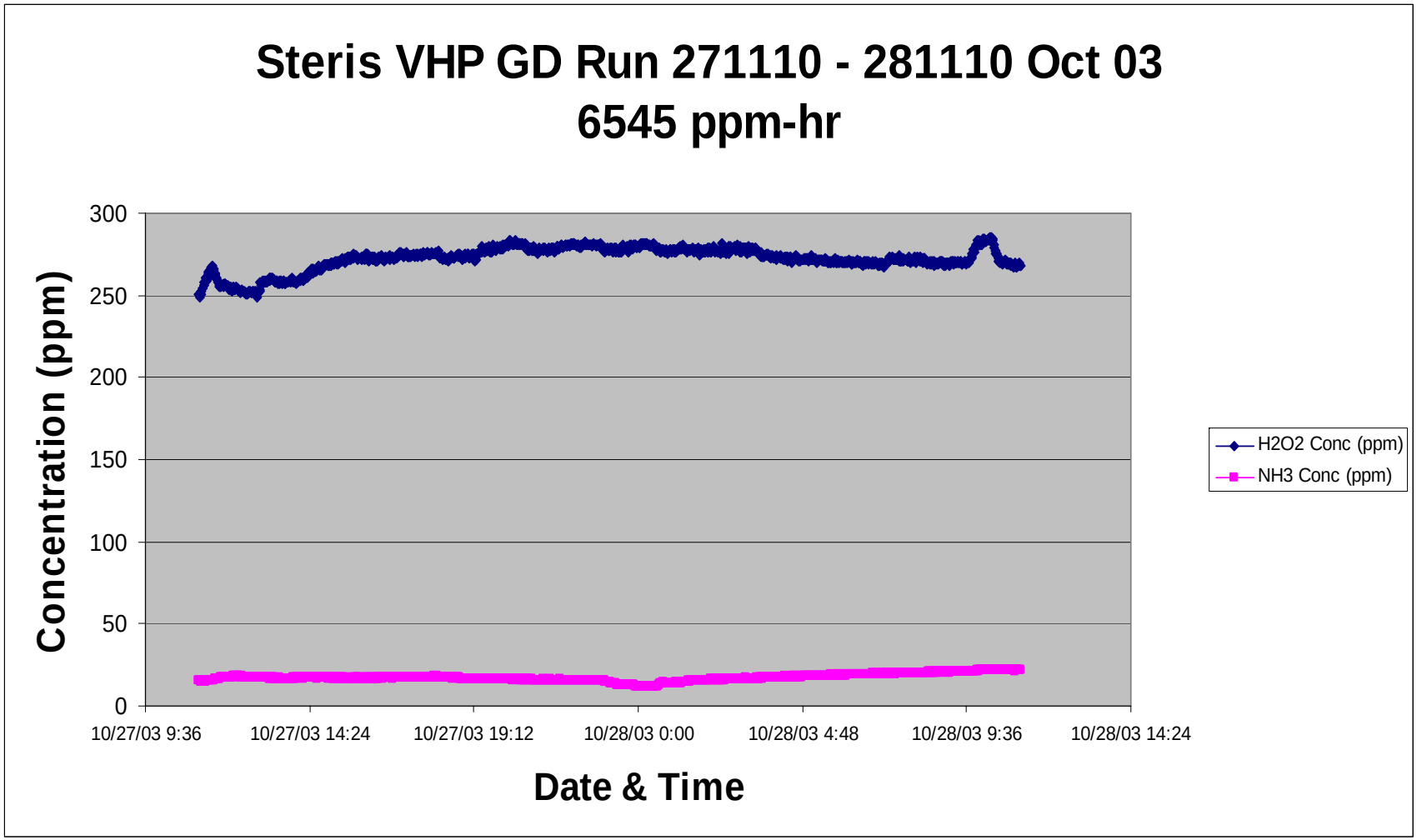
Large Chamber Test Methods

- **Contact Hazard = Natural Latex Rubber dental dam is placed in contact with contaminated substrate, held in contact by 1 kg weight for 15 minutes, then extracted with ethyl acetate and analyzed by GC-MS for amount of agent/surrogate transferred**

- **Residual Hazard = Contaminated substrate, after contact hazard test, is extracted with ethyl acetate and analyzed by GC-MS for amount of agent/surrogate remaining**

- **Headspace = Air sample taken directly over contaminated substrate plate and collected on solid sorbent tube, analyzed by GC-MS for mass of agent/surrogate captured**

Large Chamber Test Results – Typical Concentration Profile

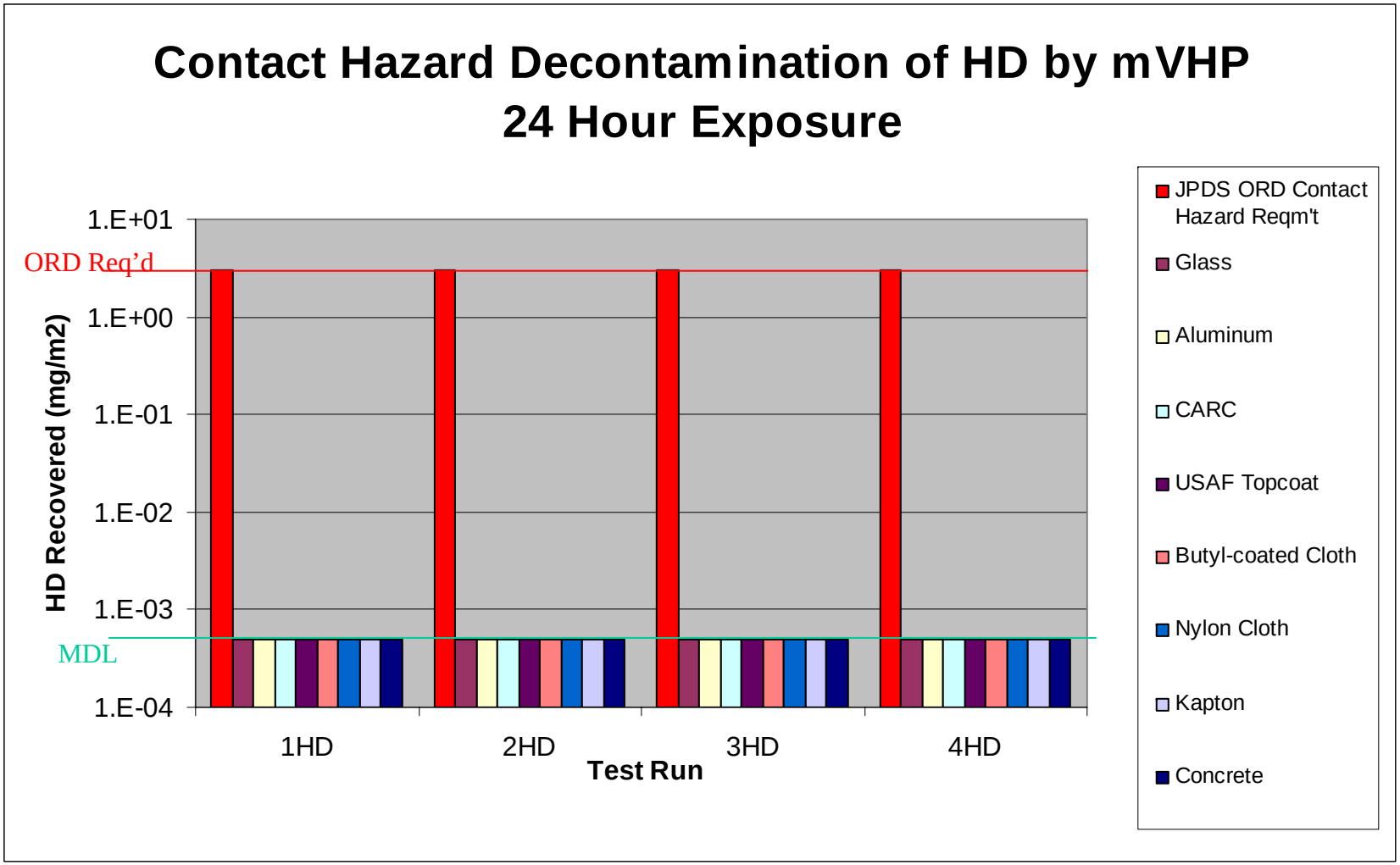


HD Background Data

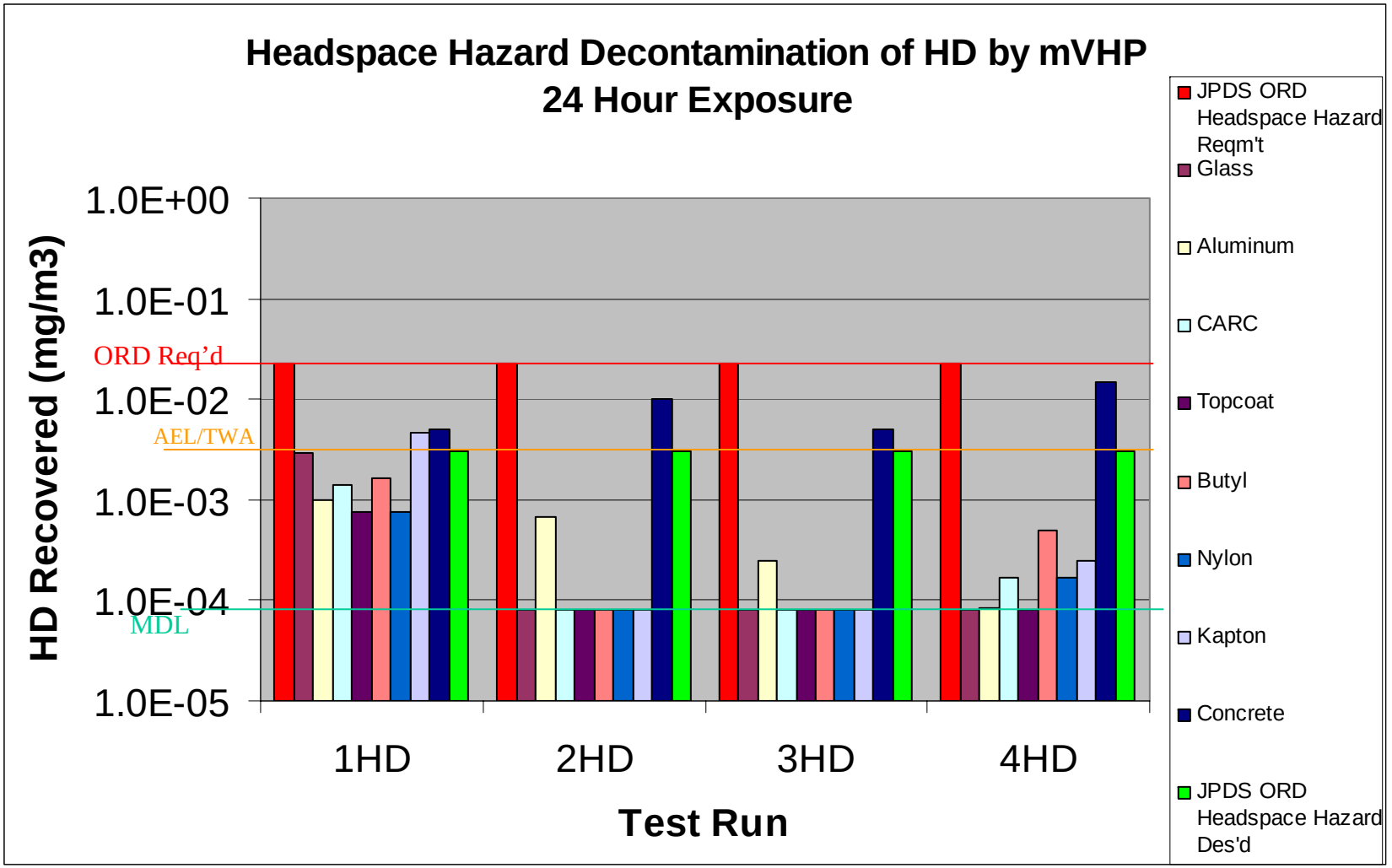
- Joint Portable Decon System ORD Requirements:
  - HD Contact/Residual Hazard: Required = 3.0 mg/m^2
  - HD Contact/Residual Hazard: Desired = 0.0 mg/m^2
  - HD Headspace Hazard: Required = 2.3×10^{-2} mg/m^3
  - HD Headspace Hazard: Desired = 3.0×10^{-3} mg/m^3
- Minimum Detectable Limits for Tests:
  - Contact/Residual Hazard: 4.93×10^{-5} mg/m2
  - Headspace Hazard: 8.33×10^{-5} mg/m^3
- Concentration x Time Values (ppm-hr)

	24-hour		**8-hour**	
	VHP	NH_3	VHP	NH_3
1HD:	956	177	**(6-hour sample)**	
2HD:	4657	337	2018	140
3HD:	6716	472	2286	165
4HD:	6484	721	2176	382

Contact Hazard Fumigation Data

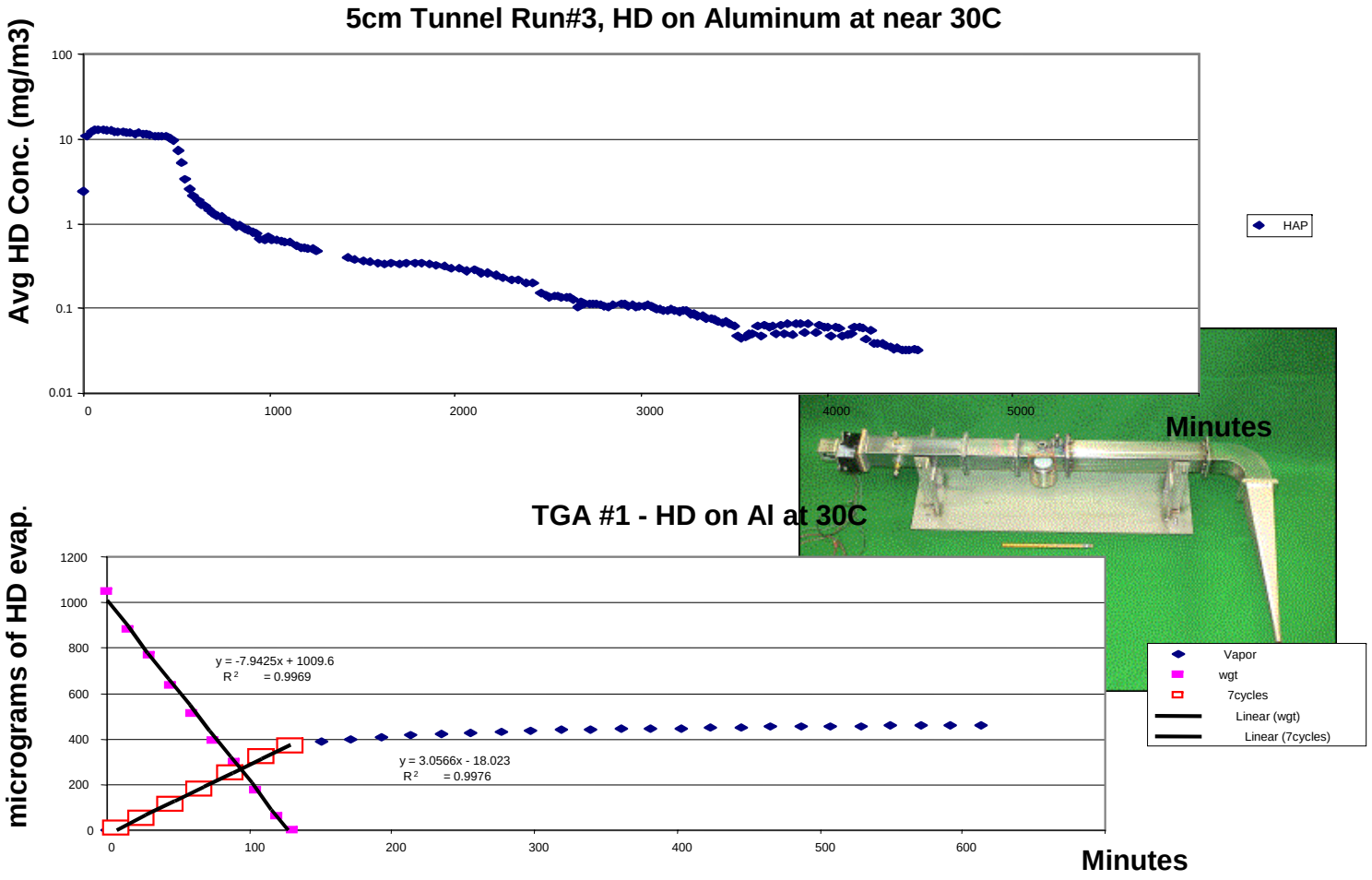


Headspace Hazard Fumigation Data

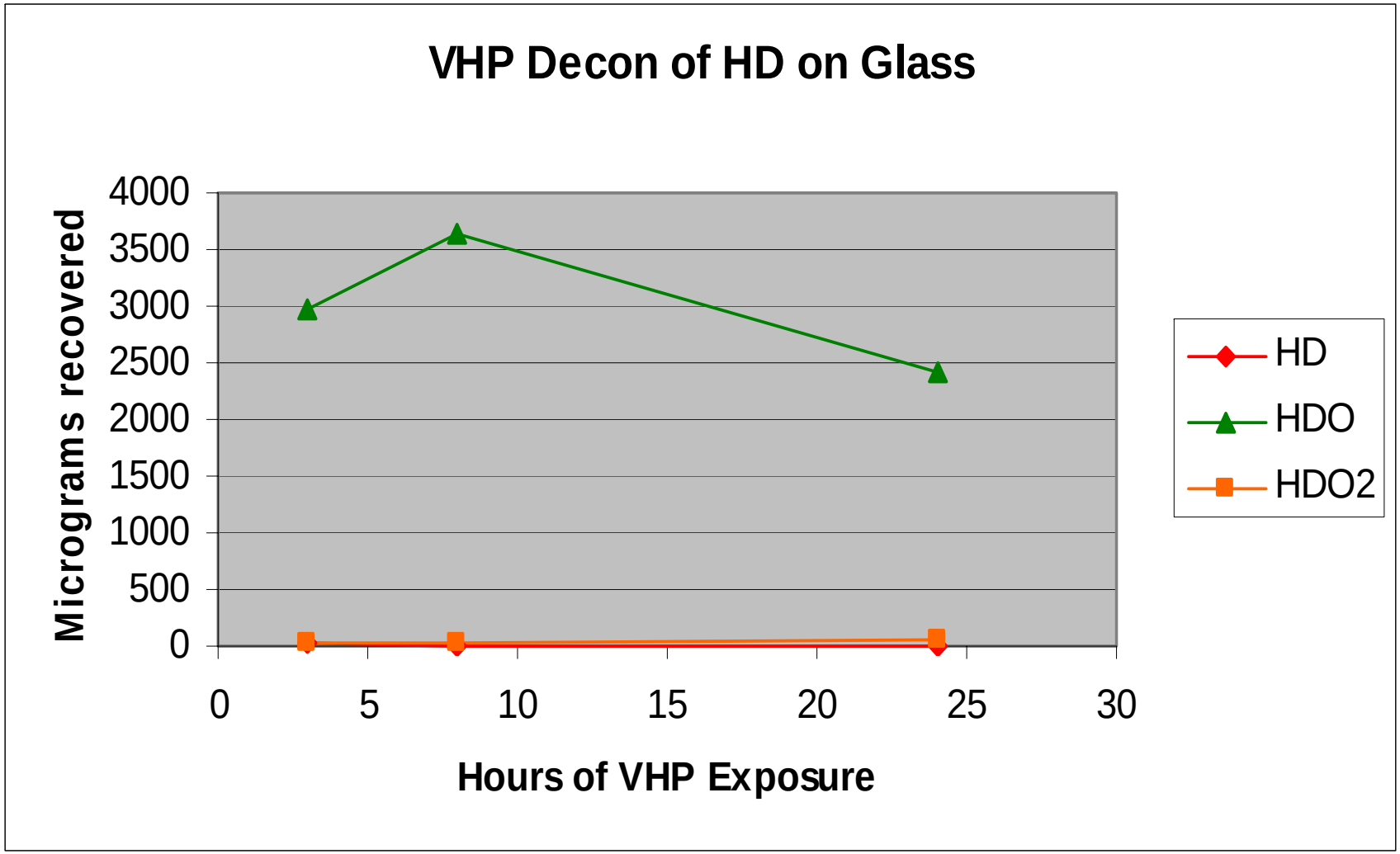


Agent Fate Baseline Data Shows ~0.7 mg/m^3 HD in headspace after 24 hours weathering; HD in headspace after 24 hr mVHP treatment 3 orders of magnitude lower, ~0.0005 mg/m^3

Lab/Wind Tunnel Data



Large Chamber Test Results – HD Reaction Products

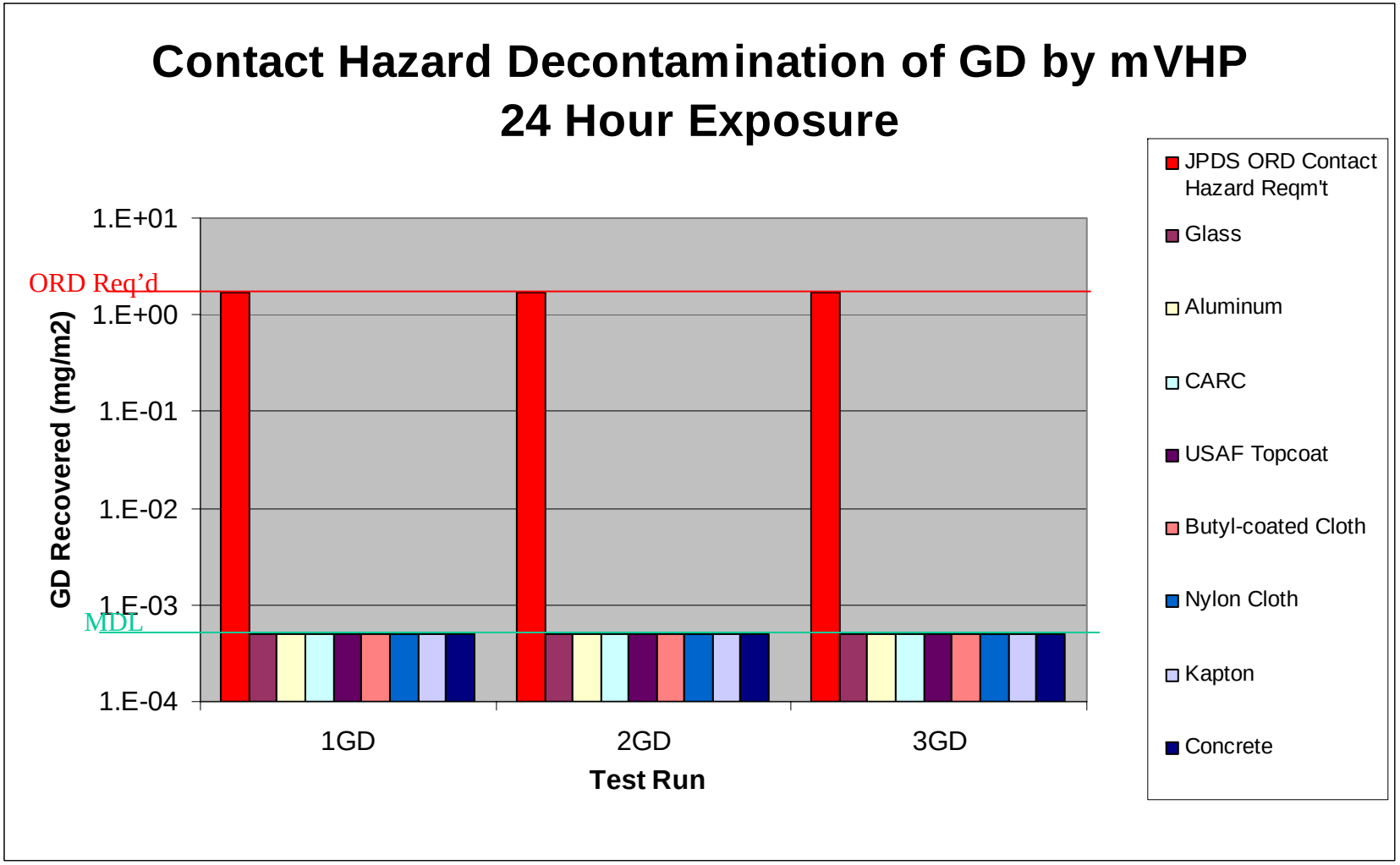


GD Background Data

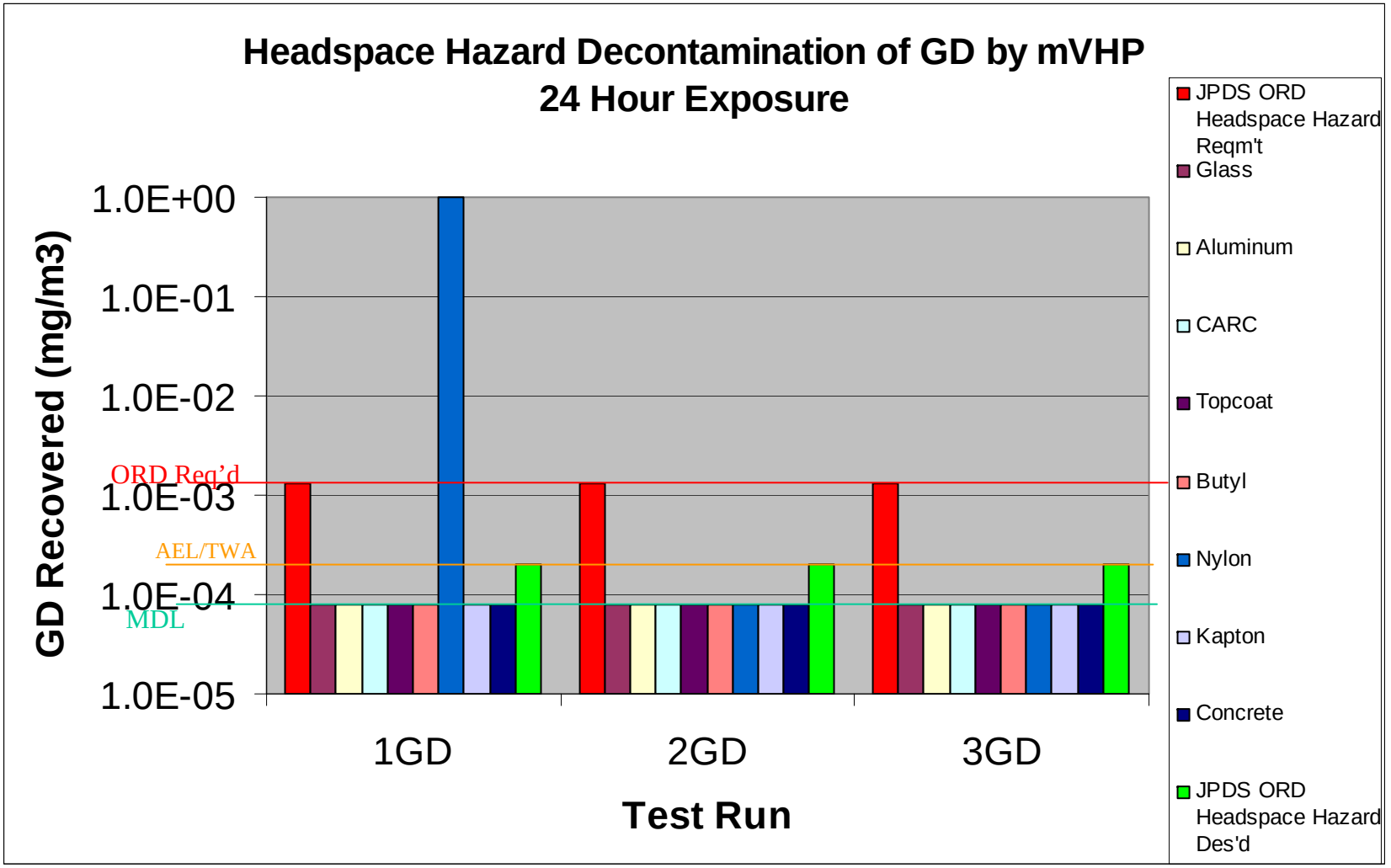
- Joint Portable Decon System ORD Requirements:
  - GD Contact/Residual Hazard: Required = 1.7 mg/m^2
  - GD Contact/Residual Hazard: Desired = 0.0 mg/m^2
  - GD Headspace Hazard: Required = 1.3×10^{-3} mg/m^3
  - GD Headspace Hazard: Desired = 2.0×10^{-4} mg/m^3
- Minimum Detectable Limits for Tests:
  - Contact/Residual Hazard: 4.93×10^{-5} mg/m^2
  - Headspace Hazard: 8.33×10^{-5} mg/m^3
- Concentration x Time Values (ppm-hr):

	24-hour		8-hour	
	VHP	NH_3	VHP	NH_3
1GD:	6549	560	2200	223
2GD:	6545	414	2138	137
3GD:	6358	379	2117	131

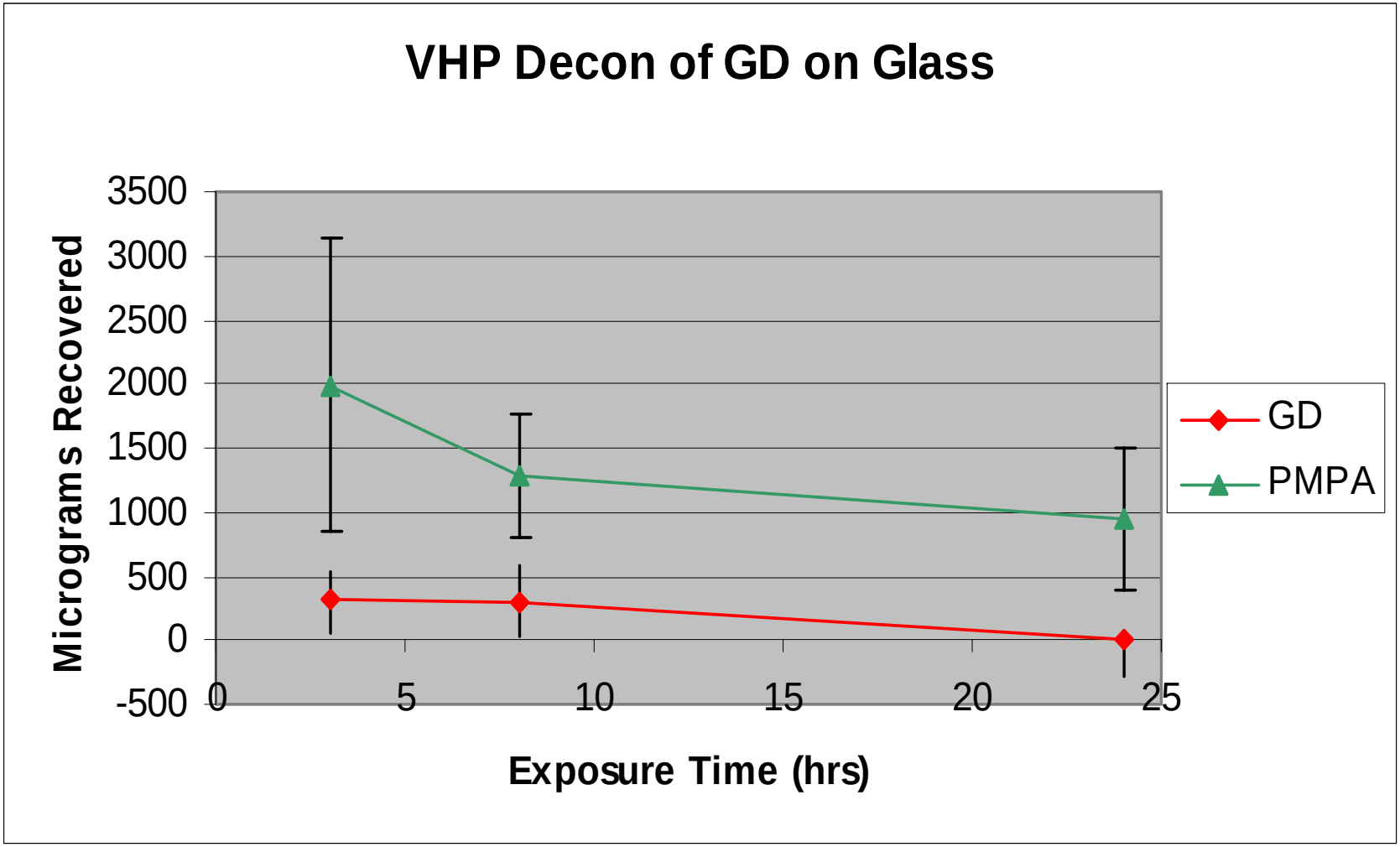
Contact Hazard Fumigation Data



Headspace Hazard Fumigation Data



Large Chamber Test Results – GD Reaction Products

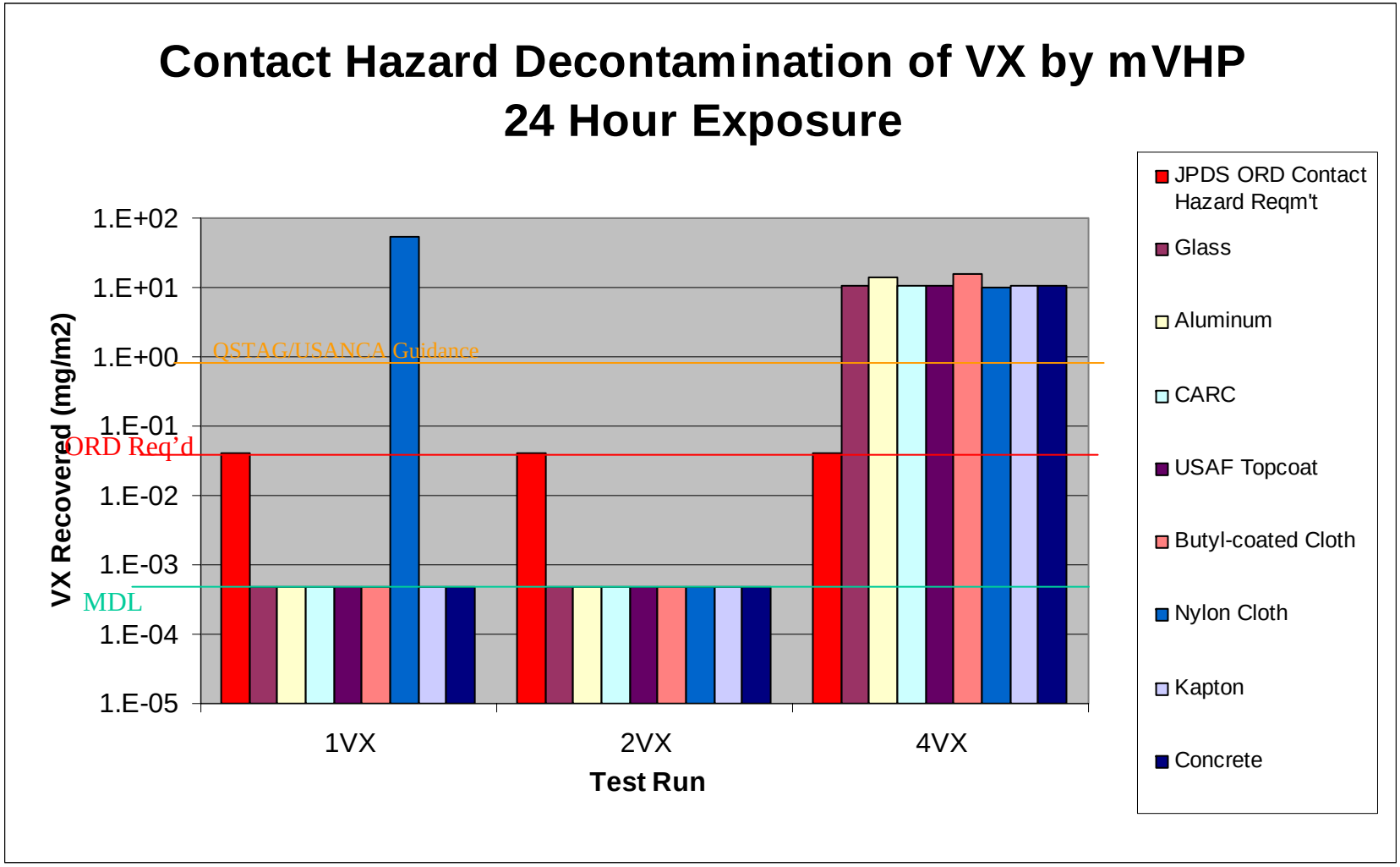


VX Background Data

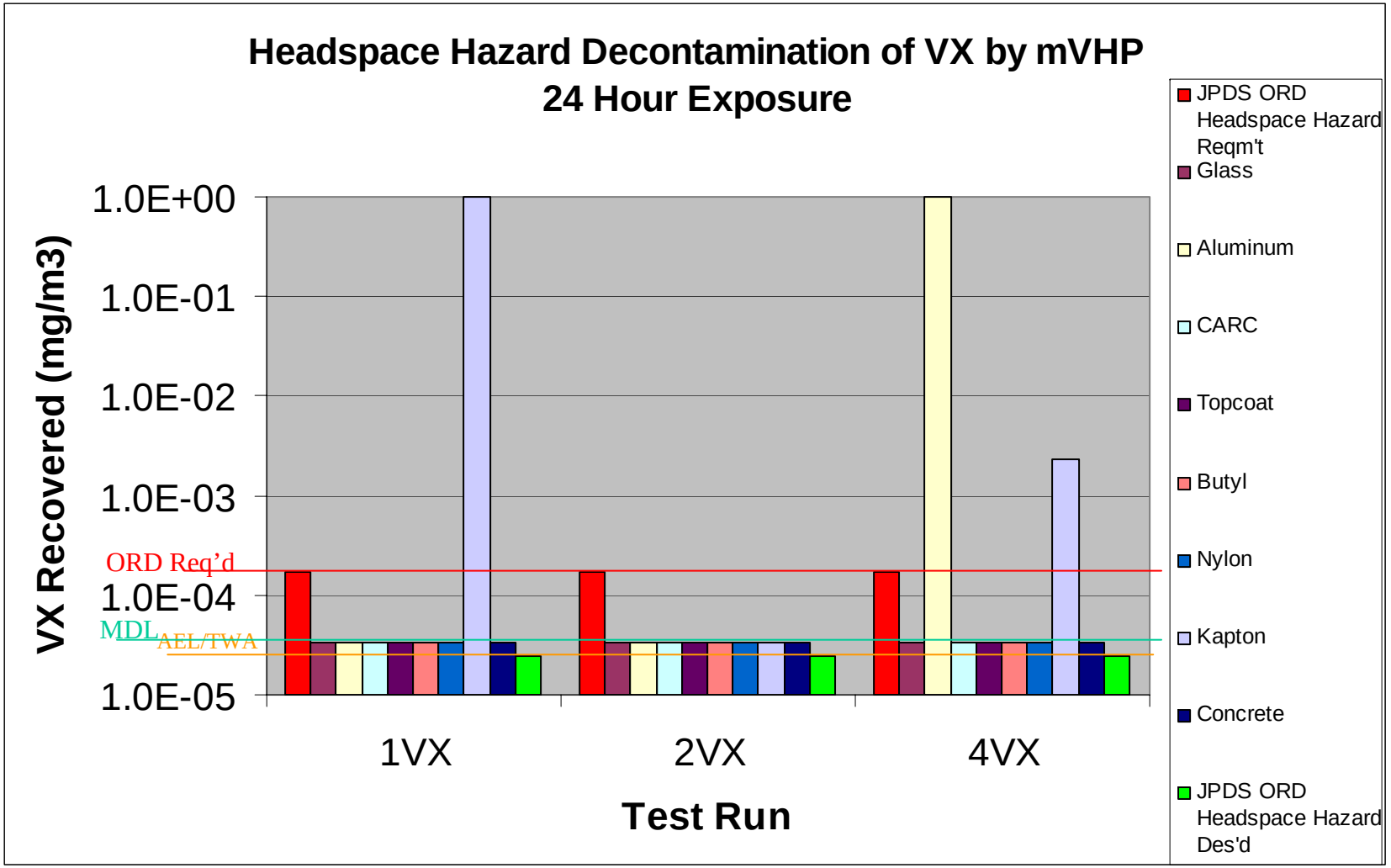
- Joint Portable Decon System ORD Requirements:
  - VX Contact/Residual Hazard: Required = 4.0×10^{-2} mg/m^2
  - VX Contact/Residual Hazard: Desired = 0.0 mg/m^2
  - VX Headspace Hazard: Required = 1.7×10^{-4} mg/m^3
  - VX Headspace Hazard: Desired = 2.4×10^{-5} mg/m^3
- Minimum Detectable Limits for Tests:
  - Contact/Residual Hazard: 4.93×10^{-5} mg/m2
  - Headspace Hazard: 3.33×10^{-5} mg/m^3
- Concentration x Time Values (ppm-hr):

	24-hour		8-hour	
	VHP	NH3	VHP	NH3
1VX	6352	488	2113	189
2VX	6182	320	1824	121
3VX	(Not Collected)		2038	103
4VX	6681	141	2109	47

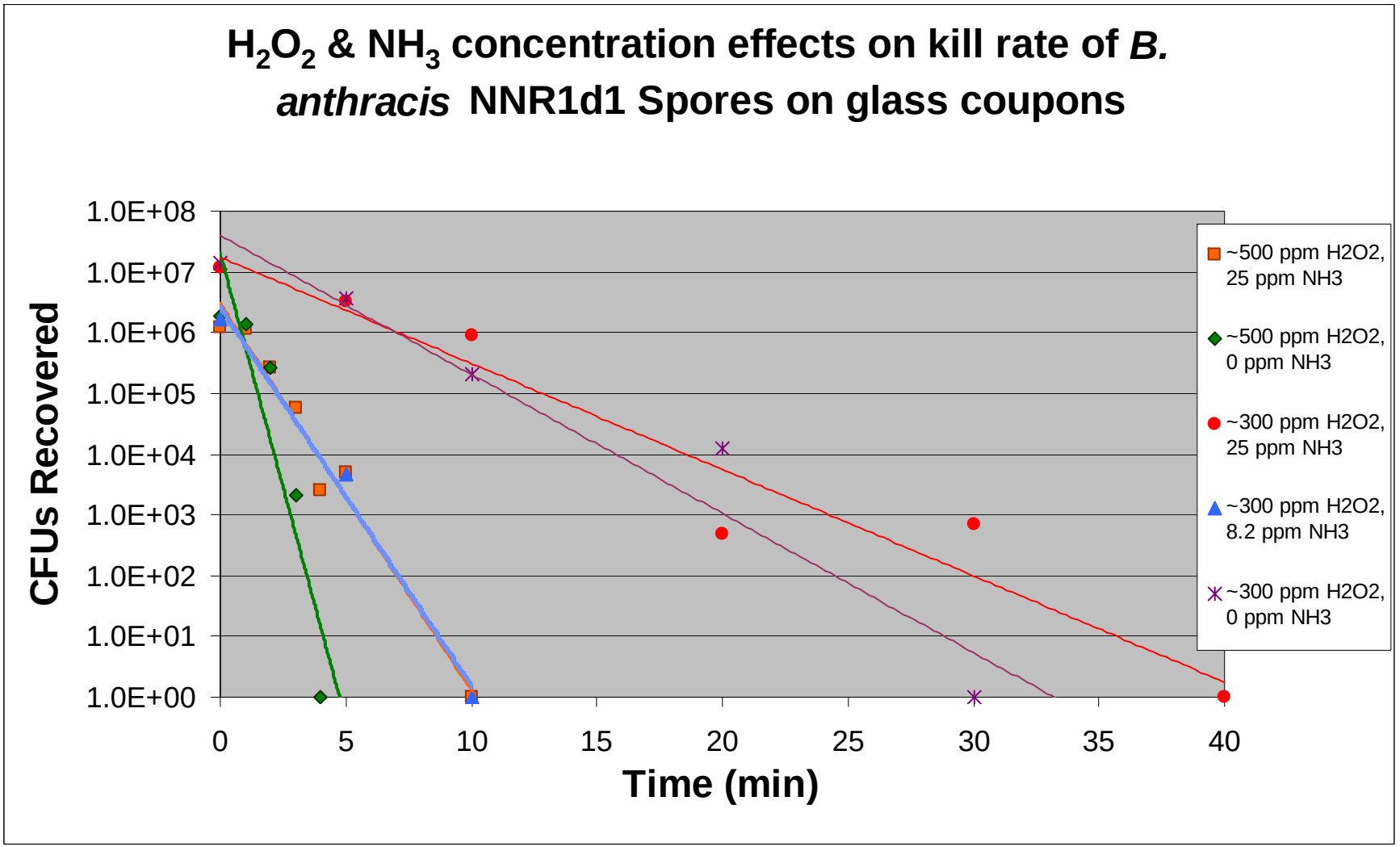
Contact Hazard Fumigation Data



Headspace Hazard Fumigation Data

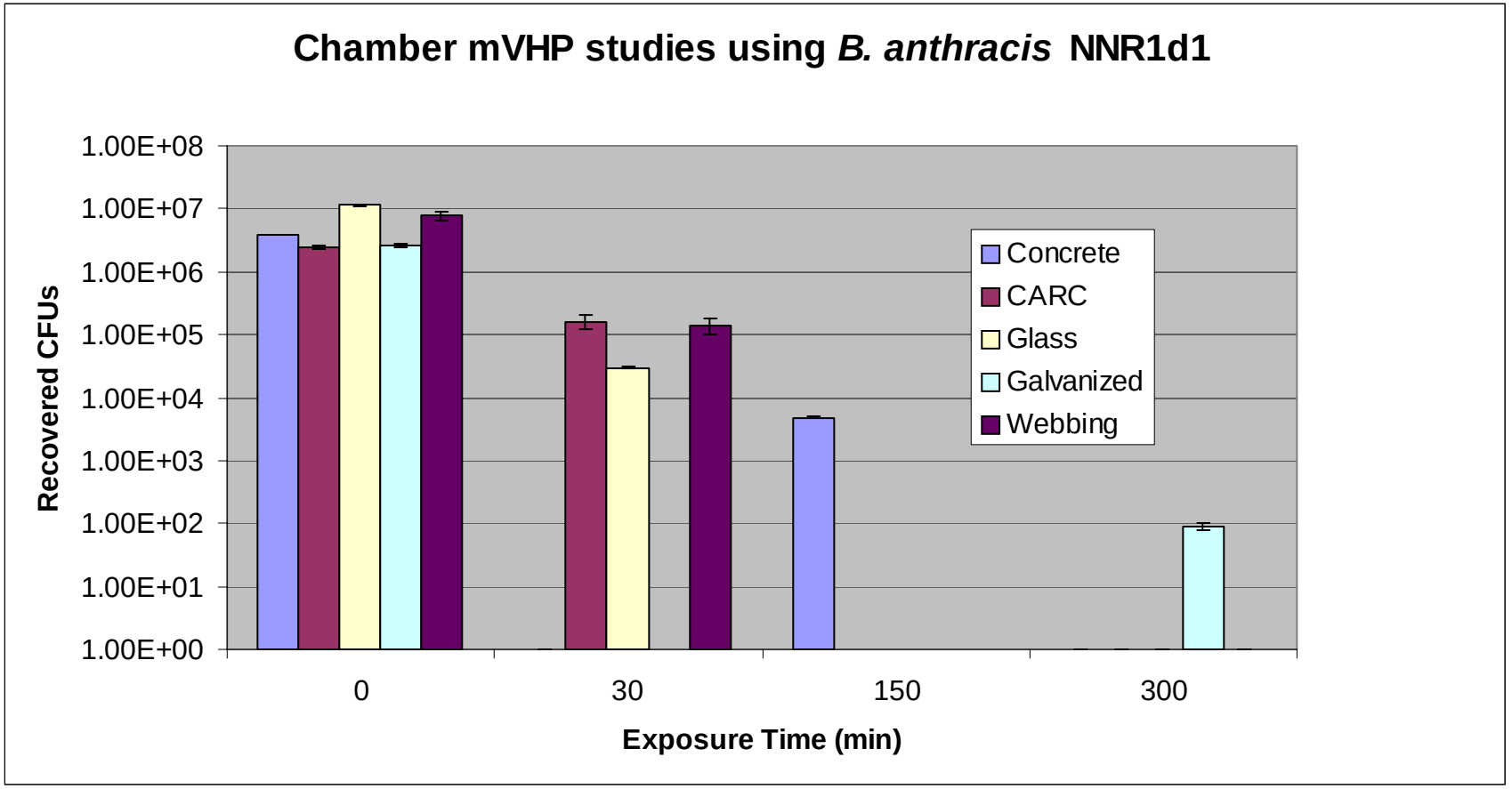


Kill Curves for VHP® and mVHP® vs. Avirulent anthrax



Kill Curves for m**VHP®** vs. Avirulent anthrax

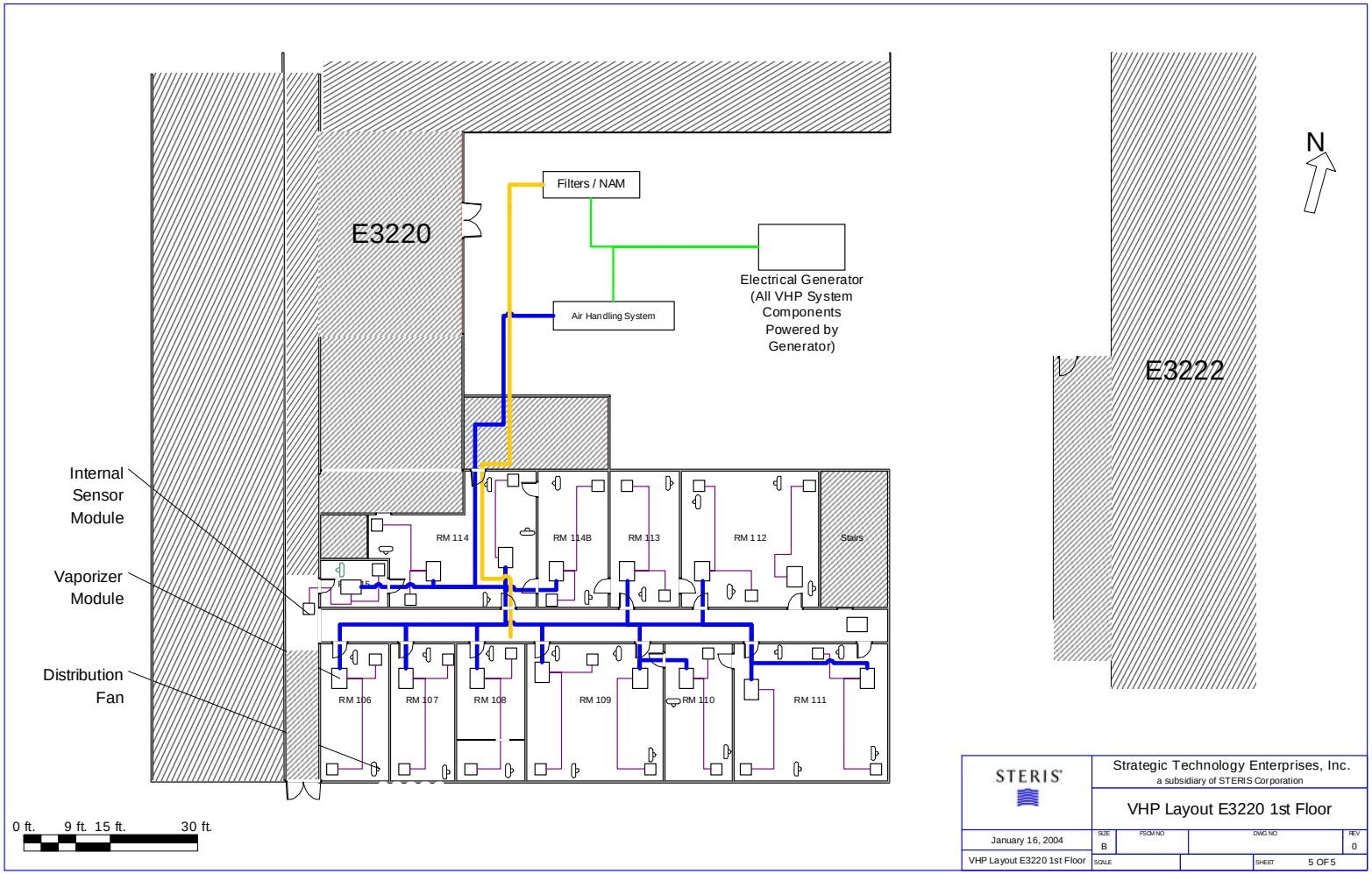
Thorough Decontamination: BW Decontamination by VHP at Room Scale



Test Results

- Chambers study is the first demonstration of fumigation-style decontamination of CW agents at the room scale
  - 24-hour m**VHP®** treatment with 250 ppm **VHP®** + 20 ppm NH_3 effectively reduces contact hazards of HD, GD, and VX to limits of detection
  - 24-hour m**VHP®** treatment with 250 ppm VHP + 20 ppm NH_3 reduces vapor hazards of GD and VX to limits of detection
  - 24-hr treatment with 250 ppm m**VHP®** + 20 ppm NH_3 reduces HD vapor hazard, but detectable amounts remain, especially on porous surfaces
- Porous surfaces may require longer mVHP® treatment times
- mVHP is <u>marginally</u> less effective as an anthrax decontaminant than VHP itself

Building Scale VHP Decontamination



E3220 VHP Decontamination Test Results

- Demonstrated ability to obtain 125, 250 and 450 ppm treatment levels in 50,000 cu. ft. volume for 5 hour treatment cycle
- Used computational modeling to model air flow in rooms and lay out distribution system
- Confirmed model results with VHP sensor readings during readiness trials
- 100% Kill of G. strearothermophilus BI's at 125ppm , 250 ppm and 450 ppm VHP treatment levels

mVHP Decontamination trial at Davis-Monthan AFB, November 2004; 100% BI kill in tests to date

C-141 with External Air Handler and NAM

QUESTIONS?